FridgeNet: A Nutrition and Social Activity Promotion Platform for Aging Populations

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Inevitably, isolated older adults gradually lose their connections with other people, and their social skills often worsen. FridgeNet encourages this population to share diet information, helping to establish a virtual community.

Research among various cultural settings indicates that older people who choose to remain in their original homes and communities, despite their children living far away, often end up living alone.[1] Based on the latest US Census, 29 percent of senior adults in the US (8.1 million women and 3.2 million men) live alone,[2] with a portion of this population gradually losing connections to families and friends because of isolated living situations and deteriorating social skills. A survey conducted by the Joseph Rowntree Foundation revealed that 19 percent of seniors in the UK who live alone communicate with their families on a face-to-face basis less than once a month,[3] with 17 percent of them in contact with families, friends, and neighbors less than once a week—they report that television is their primary form of company (www.independent.co.uk/lifestyle/health-and-families/health-news/is-this-the-loneliest-generation-8449305.html). Gradually, these people will often lose their ability and willingness to communicate with others.

The fast pace of modern life further enlarges the gap between older people and the rest of society. Many do not stay informed about the world and express diminished enthusiasm for many former interests. BBC News has reported that more than 3 million older people feel disconnected from modern life and isolated from society (http://news.bbc.co.uk/2/hi/uk_news/4395477.stm). This lack of connection to the rest of the world affects people's health and can lead to severe mental illness, such as depression.[4]

We propose FridgeNet as a way of promoting social activities for these people—this social technology assists older people in re-establishing communication with their families, old acquaintances, and new friends. By automating and encouraging the sharing of dietary information, FridgeNet helps members of this population to establish mutual support in a virtual community.

Related Work in Social Activity Promotion

Social activity promotion has been a popular area of research since the introduction of social network media. A growing interest exists concerning the design and implementation of suitable social networks for aging populations as a means of reducing their experienced social isolation.[1,2] Some researchers have suggested that older people should participate in social networks to virtually connect with their families and friends, particularly if they live in isolated environments. They believe that a convenient, interactive platform can help people overcome their isolated living situations and enable an aging population to use social technology to participate in discussions with their peers and families.[3,4] For example, Oliver Burmeister demonstrated that online communities could provide a space for older adults to share their life experiences and to create mutually supportive virtual communities. As older participants increase their online activities, they generally begin to value their participation in and contributions to a virtual community.[5]

Common topics of interest among an older population include chronic disease, personal life histories, and diet suggestions. Internet and wireless health technologies can provide health-related information, record and update personal and medical information, and offer remote health services to the community. Individuals' daily activities and personal health conditions can be monitored, recorded, and summarized using cloud healthcare services, providing valuable healthcare information for personalized diagnosis. However, medical information is so personal and private that most people don't like to share it openly. John Vines and his colleagues observed that some people feel uncomfortable with in-home monitoring systems. They reported that these systems seem to peek into their life every day, even though the purpose of continuous monitoring carried out by caregivers is good for their health.

Healthy diets and lifestyles are another topic to be addressed.[7] Because body composition and health conditions vary according to age, region, and health phase, the population has differing nutritional requirements and information update needs.[8,9] Elizabeth Manafo and Sharon Wong as well as Ashley Anker and her colleagues found that information-seeking behaviors of older adults could contribute to their health and well-being.[10,11] Because the process of searching for nutrition information is time-consuming and often unstructured, some researchers suggest building a social interface to encourage the exchange of food tips or recipes.[12,13] Andrea Grimes and Richard Harper observed that food could bring people together and have discussed the role of technology in human-food interaction.[14]

Requiring people to remember the food they consume daily and compare it with their recommended intake can be impractical because many are likely to forget or have an unclear understanding of what they've eaten. A system that lets people log their dietary intake and look up nutrition information would alleviate this problem. The logged and cached nutrition information could then be shared with other peers who have similar nutrition-related concerns or with family members who want to participate in care.

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Design Considerations

As Tanvir Ahmed and Haboubi Nadim discussed, nutrition is an important element of health for the older population that affects the aging process.[5] Important macronutrients and micronutrients include a variety of proteins, vitamins, and minerals, such as calcium, potassium, folate, iron, zinc, and vitamins A, B6, B12, C, and D. Reduced food intake or an unbalanced diet tend to result in vitamin and mineral deficiencies for

older people. C.J. Bates and colleagues indicated that for people aged 65 years or older, vitamin D intake is far below what's recommended.[6] Benjamin Tang and his colleagues described how calcium in combination with vitamin D supplementation has a positive correlation in prevention of bone fractures and osteoporosis in older people.[7,8]

To avoid overwhelming older people with excessive nutritional information and to help them quickly establish bidirectional communication in a virtual community, share their diet styles and comments, and further promote their physical social activities with their peers, FridgeNet focuses on only calcium, iron, vitamin C, and vitamin D. We used these four nutritional components to design diet tracking, nutrition analysis, and nutrition information visualization in the FridgeNet system.

FridgeNet: Getting Social with a Diet Hook

FridgeNet (see Figure 1a) records personal food intake information and promotes communication and social activity among senior citizens. The system uses sensor-equipped processing units (tablets mounted on standard refrigerators) and a cloud service to store and propagate food information. The system automatically stores users' dietary histories and downloads the corresponding nutritional information. Similar to existing social networking websites, the system lets users post comments, pictures, and voice messages (see Figure 1b). The tablet system also propagates aggregated diet information among peers. Users can evaluate their nutrition intake by comparing their dietary history with other FridgeNet users'.

Sensor-Driven Interaction

Common inertial sensors on the tablet automate the data-recording process. When a user opens the fridge, the
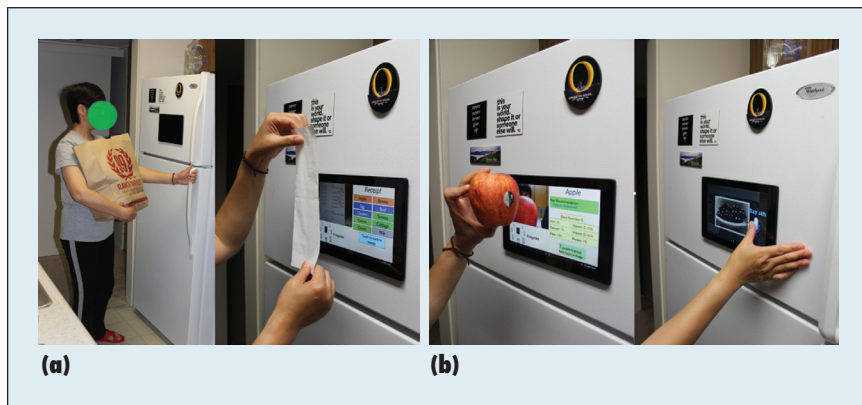

Figure 1. FridgeNet's (a) implementation and (b) main page of the recommended food photo stream. The system automatically stores users' dietary histories and downloads the corresponding nutritional information.
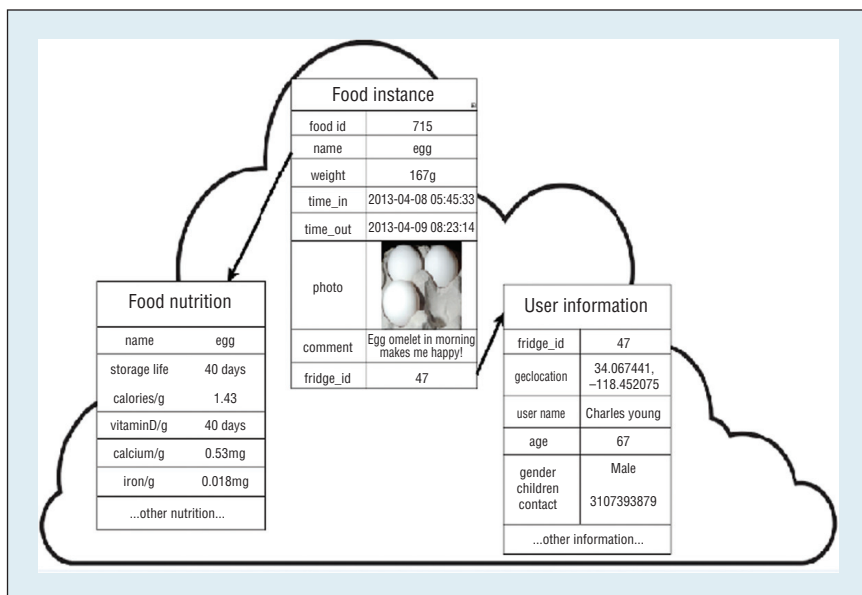

Figure 2. FridgeNet's internal data structure. Each FridgeNet entity stores structured food instance, food nutrition, and user information in its local database.

built-in accelerometer detects the corresponding fluctuation and triggers a message that instructs the user to scan a grocery receipt (or select a food item name) and then take a picture of the food item removed from the fridge. Both the scanned receipt image and food snapshot are uploaded to a Web service after recording. An optical character recognition library installed on the server end first recognizes the item names on the receipt (www.mathworks.com/matlabcentral/fileexchange/18169-optical-character-recognition-ocr) and

then synchronizes them with the local database (see Figure 2). Ever FridgeNet user's intake information is accumulated and periodically updated in the cloud. FridgeNet then calculates the average of the intake input, which participants can compare with their own diet habits (see Figure 3).

Diet Tracking and Nutrition Analysis

Users can browse nutrition information through simple clicks on the tracked food list. If a food image is available,
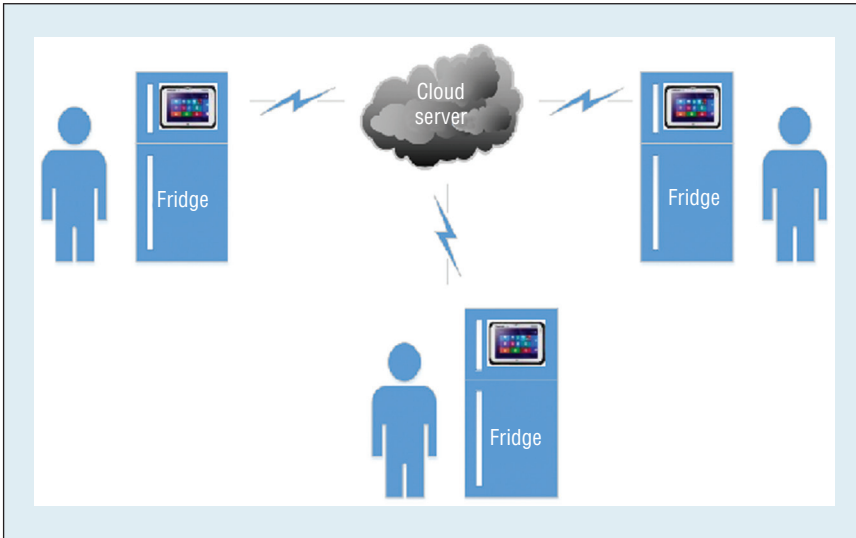
Figure 3. FridgeNet's network structure. Local databases receive periodic synchronization and updates from a centralized server through a standard client-server network architecture.
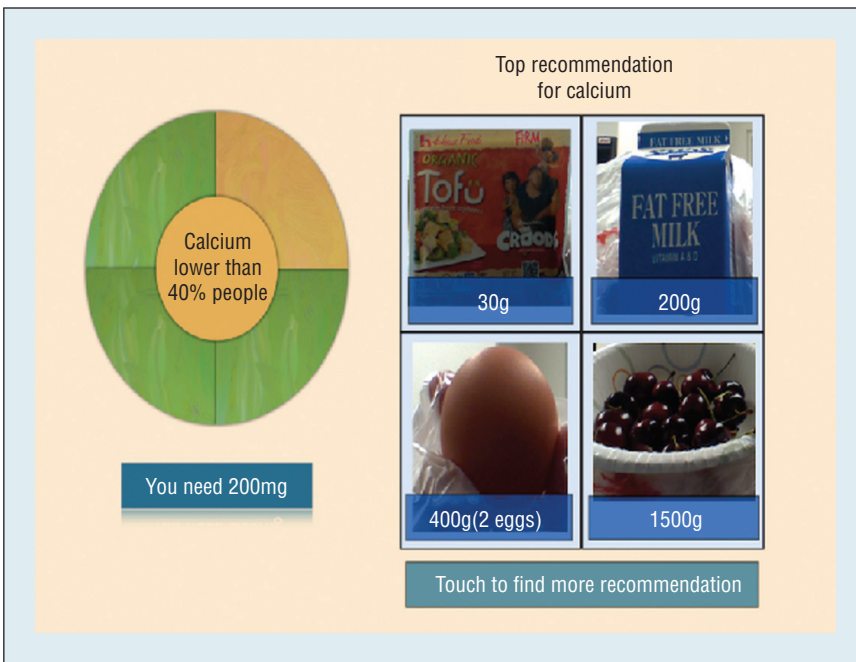

Figure 4. An example of FridgeNet's nutrition information visualization. Deriving from periodic synchronized information, FridgeNet compares and visualizes nutrition intake insufficiency for every subject. Four nutrition components are tracked (iron, calcium, vitamin C, and vitamin D), and a colored pie diagram and instructions are displayed when a user interacts with the FridgeNet user interface.

clicking on the image displays that item's nutrition information. Personal dietary history can be tracked and aggregated based on receipt-scanning history. Users mark and record consumed food in their stored dietary history, with daily and weekly personal nutrition intakes calculated by accumulating the intake nutrition of all consumed food items. FridgeNet periodically synchronizes individual dietary history, together with the cached nutrition information of newly added food, to the cloud server. An algorithm aggregates and calculates users' average daily and weekly nutrition intake, and FridgeNet retrieves this summarized information.

Nutrition Information Visualization

FridgeNet compares the differences in diets between users and their peers. The resulting chart (see Figure 4) is split into four sections that represent the four nutrition elements we focused on: iron, calcium, vitamin C, and vitamin D. When a user selects one of the four sections, the comparative results between the user and his or her peers appear in the center of the screen, and a popup notification appears to indicate the nutrition intake the user requires for that element. Each section of the chart is color coded based on the level of nutrition that the user requires: green represents "sufficient," yellow "might be insufficient," and red "insufficient." Users can quickly identify the nutrition component they lack. Information is recalculated when the FridgeNet tablet retrieves an update from the server. The right side of the chart displays recommended foods for the user. The types of food recommendations are based on preloaded and peer-recommended food types. The order of recommended food is sorted based on the amount of nutrition each item contains and the user's requirements.

Food Recommendations and Responses

Whenever a food item is removed from the refrigerator, the user is expected to mark the item name as consumed from the scanned receipt list and to take a picture of that item. This action marks the food item as eaten, and its nutrition information is recorded in the user's daily log. If the food item isn't fully

consumed, the user should take another picture of the food item or simply input how much of the food remains. Users can selectively choose to provide comments on the food items they like. FridgeNet encourages and facilitates recommendations to peers. When users want to recommend a food item, they first press and hold the onscreen name or image of that item. A popup menu confirms the recommendation, and users can add text or voice messages to more adequately describe it. Similarly, if users discover that a recommended food is healthy, they can "like" the item (by pressing an indicator on the screen), provide comments, or place the food item in their virtual shopping cart.

Buy2+gether

FridgeNet is not only designed to promote virtual social interaction among older people but also to encourage them to meet face to face. The Buy2+gether service (see Figure 5) enables users to send shopping invitations to their neighbors to meet and purchase food together. Users can send shopping invitations

- based on nutritional requirements,
- to the nearest three neighbors, or
- to friends, family members, or acquaintances (email address required).

The person who initiates the shopping invitation can specify what he or she wants to go, when, and the deadline to accept the invitation. If peers accept the invitation within the specified time frame, they can form a group and share their contact information. FridgeNet helps determine the most convenient location for the group to meet based on Wi-Fi position information.

Field Study

We evaluated FridgeNet with a group of 15 older people (10 women and 5 men) who lived alone and were
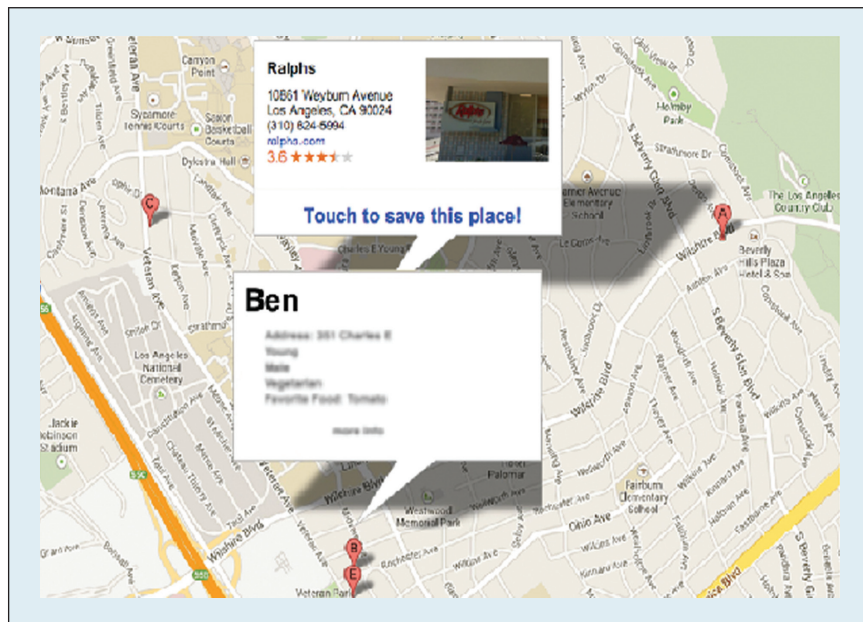

Figure 5. A screenshot of the Buy2+gether application. The Buy2+gether service lets users send shopping invitations to their neighbors to meet and purchase food together. Here, Ralphs is suggested as the most convenient location for the group to meet based on their geographical information.

between 55 and 76 years of age (average = 66.27; standard deviation = 6.13). Some participants already knew other participants, but they didn't regularly interact before the trial. Among the 15 participants, only five had experience with using tablets for daily entertainment, and none of them regularly used social networking media such as Facebook or Twitter.

Procedure

The whole study lasted three months. At the beginning of the experiment, we taught every participant the concept and function of FridgetNet, including its sensor-driven interaction, diet tracking, visualization, and Buy2+gether service. To ensure safety, we encouraged participants to consult with their personal doctors before changing their diets, and we fully explained the health effects associated with iron, calcium, vitamin C, and vitamin D deficiencies, as tracked by the FridgeNet prototype. We then trained participants to scan their grocery receipts, photograph food, read food nutrition information, respond with

a "like," provide comments and recommendations, and send invitations to specific groups of people. We asked participants to use the FridgeNet system to search for foods containing high percentages of calcium. (Additional information about food nutrition wasn't provided because we expected participants to enjoy the process of determining nutrition requirements and locating that information via FridgeNet more than they would learn in a lecture about nutrition.)

Data Collection

Data from each FridgeNet entity was aggregated to the server, and each data stream included a unique ID. We produced mapping tables to match unique IDs to the participants' personal information; this information wasn't accessible to the participants. At the end of study, we collected the tablets to examine if any data wasn't correctly uploaded to the cloud servers and removed any of the participants' personal information. FridgeNet collected food nutrition and tablet log information such as the number of
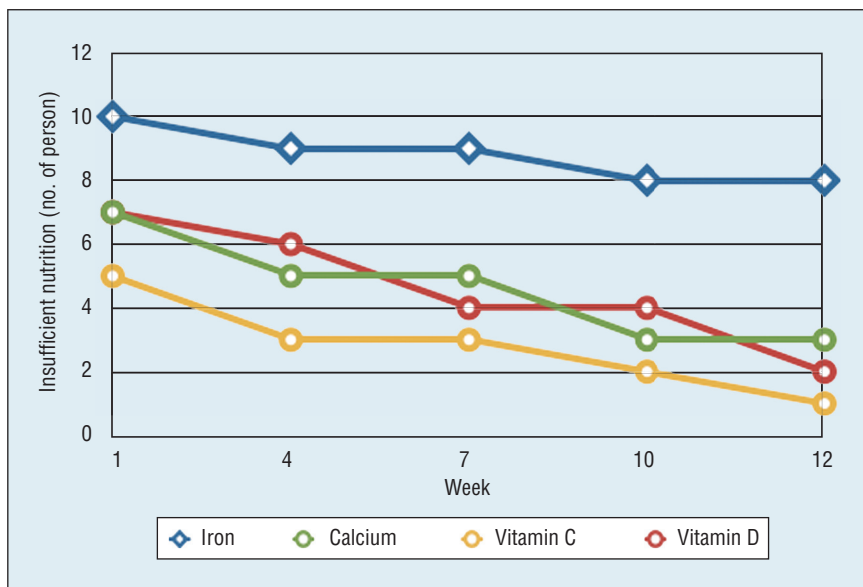
Figure 6. Four types of nutrition components: iron (blue), calcium (green), vitamin C (yellow), and vitamin D (red). Most participants learn to find appropriate foods for insufficient nutrition, although many still seem to have difficulty finding food with ample iron elements.

"likes" associated with a food item, comments, and Buy2+gether invitation messages.

Results

This study attempts to answer three questions: Does FridgeNet assist older people in choosing healthy foods? Does FridgeNet promote online social activities for participants? Do the participants engage in more physical social activities after using FridgeNet than they did before using the system?

To answer the first question, we must assess the number of participants who had insufficient nutrition intake change during the study period. To answer the second, we considered two categories of statistics: the number of passive online activities in which the participant engages, such as viewing food items or messages from peers, and the number of active online social activities in which the participant engages, such as responding to peers' recommendations with "likes" and personal comments. The last question is answered by determining the way in which Buy2+gether was used during the 12-week study.

Insufficient Nutrition Intake Statistics

Analyzing nutrition intake trends helps us determine whether FridgeNet improves participants' food selection. Figure 6 presents the number of participants exhibiting insufficient nutrition intake in 12 weeks for iron (blue), calcium (green), vitamin C (yellow), and vitamin D (red). The figure shows that some of the participants exhibited lower levels of nutrition intake sufficiency in the first week. Twenty-nine insufficient-intake events were recorded in the first week among 15 subjects, but only 14 insufficient-intake events were marked at the end of the study (51.7 percent improvement compared with the number in week 1). This phenomenon indicated that the diets of the participants improved during the study period.

One participant, a vegetarian, said she never considered that she might have insufficient levels of nutrition intake. She quickly discovered that spinach, recommended by another vegetarian peer, could be an appropriate iron supplier for her. Some of the participants said they worried about insufficient nutrition and, therefore, they required a

system such as FridgeNet to determine their nutrition needs. Based on this feedback and nutrition intake trends, we determined that FridgeNet changed dietary behavior in those participants who possessed low levels of nutrition and helped them make better food choices.

Click Numbers for Recommended Food

Determining the number of clicks produced by each participant is an effective method of evaluating the frequency of FridgeNet use in participants' daily routines. Statistics on peer-recommended foods and the number of clicks associated with those foods indicate levels of dietary improvement. Figure 7 presents the weekly average click counts of all 15 participants.

Participants recommended 47 foods in addition to the 50 preloaded food types. We found that 76.3 percent of the recommended foods were selected more than once in the 12-week period. In total, 1,273 clicks occurred for all recommended foods in the course of the 12 weeks. On average, each person produced 7.07 clicks per week. Although some individuals produced more clicks than others, the click distribution shows that every participant used FridgeNet frequently to view peer recommendations, indicating that the information obtained through FridgeNet was valuable to them.

Number of "Likes" and Comments

In addition to determining whether FridgeNet provides valuable information to participants, we investigated whether FridgeNet promotes online social activities for them. Specifically, we attempted to determine whether FridgeNet encouraged them to acknowledge and comment during their online interactions with peers. First, we analyzed the numbers of "likes" and comments and the trends associated with them.

Figure 8 reveals that the participants required approximately two weeks to familiarize themselves with the FridgeNet system: only a few "likes" and comments were posted in the first week. The bulk of the comments and feedback started to appear during week 3, when 30 "likes" and 15 comments were posted. By week 12, the number of "likes" tripled and comments doubled, revealing that an increasing number of people were engaged in actively providing feedback. Even if they didn't comment about a certain food type, they still participated. We also found that certain food nutrition information was controversial—for example, although spinach contains abundant amounts of iron, many participants deemed it a potential cause of gallstones. Numerous discussions occurred about this concern, and one participant stated that he read some articles online to corroborate his stance. Clearly, FridgeNet encouraged people to share their knowledge and life experiences, with most of the participants interested in and willing to join discussions.

Number of Replies to Buy2+gether Invitations

FridgeNet helped build a virtual community focused on the topic of a healthy diet, but it was also expected to promote physical social activities for older people by introducing the Buy2+gether service. Unfortunately, only 11 shopping invitations were sent and six accepted during the 12-week study, indicating that this service wasn't used very often. We recorded seven events, but all seven only involved a total of five people.

Figure 9 shows the shopping group that originated with two users, grew to three people by week 7, and to five people by week 10. The two group leaders were interviewed after week 12 and stated that they preferred buying food
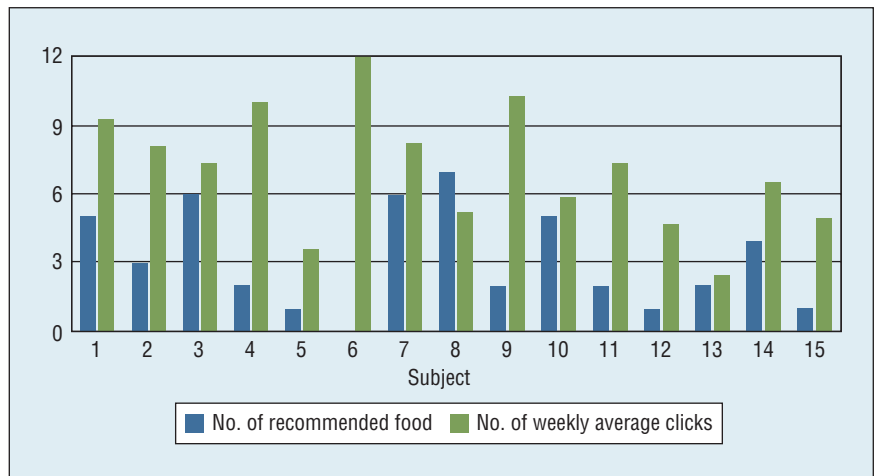

Figure 7. Click numbers of all 15 participants for recommended food. Most participants check their peers' recommendations frequently and sometimes recommend their own favorite food.
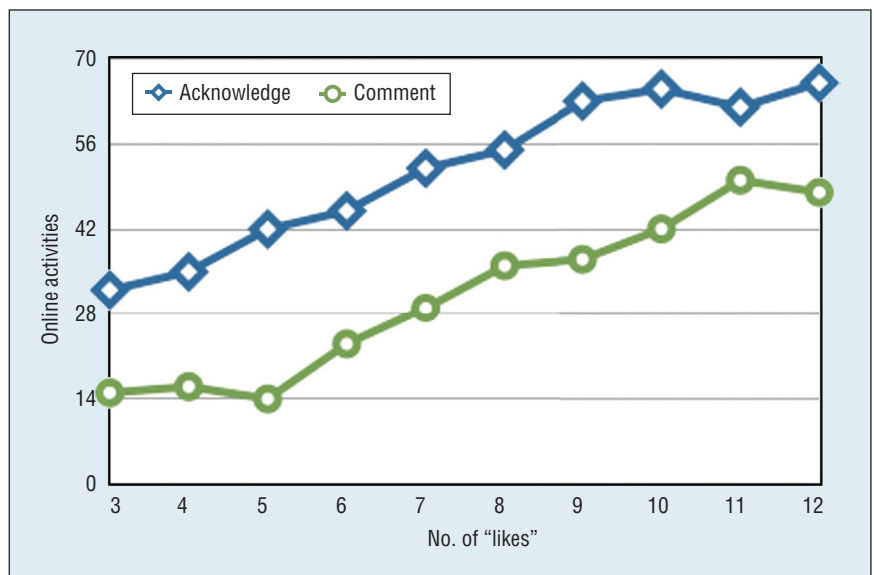

Figure 8. Feedback and comments in the FridgeNet system within 12 weeks. Although most people were more likely to "like" the recommended food than leave comments, the increasing trend of both plots indicates that users became more active in participating in FridgeNet's online social activities in general throughout the study.

with someone with whom they felt comfortable, selecting friends based on replies to their recommendations rather than on those who possessed similar food requirements—the two leaders knew each other from participating in online discussions about food. This demonstrates that online discussion about food nutrition can enhance understanding and familiarity among senior adults. Older people can more

adequately use this system if frequent online interactions or regular social events occur that help them become familiar with their peers.

FridgeNet provided a convenient framework, topics for discussion, and a valuable healthy diet database. Nevertheless, the prototype revealed some limitations. Although debatable

Figure 9. Participants using the Buy2+gether service within 12 weeks. The same group of people, labeled B, K, T, J, and A, uses this system, and the group grows larger with time. The black circle shows the initial group, with K joining later, followed by J and A.

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nutrition information can be a topic for general discussion, a doctor's input was expected, too—as one participant remarked, "I like discussion, but I love conclusion." The FridgeNet community didn't include medical or healthcare-related professionals, so if certain discussions contained errors or confusion about nutrition information, they weren't necessarily corrected. A possible solution is to recruit certified medical professionals to monitor and participate in FridgeNet's online discussions or to encourage informed family members to join discussions. Users suggested that FridgeNet could also include more intelligent grouping methods for recommending food based on different types of common illnesses or pre-existing conditions—an idea that requires access to personal and medical information. A future study direction could be in evaluating the trade-off between distinct personalized healthcare scenarios and access to personalized information. ∎

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